Patent claims

1. A method for determining a friction coefficient value (Fμ) which represents the coefficient of friction present between the underlying surface and a vehicle tire,
in which a wheel slip value (λij) is determined for at least one vehicle wheel, said value (tij) describing the wheel slip present at this vehicle wheel, and
in which the friction coefficient value (Fμ) is determined as a function of the wheel slip value (λij), characterized in that, during a predefined operating state of the vehicle, wheel slip values (λij) are determined at various times, in particular successive times, and the frequency distribution of values is determined for these wheel slip values (λij) or for axle-related slip values (λ_{VA}, λ_{HA}) which are determined as a function of these wheel slip values (λij), with the friction coefficient value (Fμ) being determined by evaluating this frequency distribution of values.

2. The method as claimed in claim 1, characterized in that the wheel slip values are determined as a function of a velocity value (vref), with a distinction being made between a case of driving and a case of braking during the determination of the velocity value (vref).

3. The method as claimed in claim 2, characterized in that during the determination of the velocity value (vref) gradient limitation is carried out in such a way that the change over time in the velocity value which is to be determined is limited.

4. The method as claimed in claim 1, characterized in that the velocity change value (a_{x-Filt}) which describes the acceleration behavior and/or deceleration behavior of the vehicle and/or a yaw rate value ($\dot{\Psi}_{fil}$) which describes the filtered yaw rate of the vehicle are additionally determined and taken into account during the determination of the friction coefficient value (Fμ).

5. The method as claimed in claim 1, characterized in that the predefined operating state of the vehicle is defined by a velocity change value (a_{xFilt}) and/or by a yaw rate value ($\dot{\Psi}_{fil}$).

6. The method as claimed in claim 1, characterized in that the predefined operating state of the vehicle is straight-ahead travel during which minimum acceleration or minimum deceleration occurs.

7. The method as claimed in claim 1, characterized in that a velocity value (vref) which describes the vehicle reference velocity and/or a yaw rate value ($\dot{\Psi}_{fil}$) which describes the filtered yaw rate of the vehicle and/or a lateral acceleration value (ay) which describes the lateral acceleration of the vehicle are determined and taken into account during the determination of the friction coefficient value (Fμ).

8. The method as claimed in claim 1, characterized in that the predefined operating state of the vehicle is defined by a velocity value (vref) and/or by yaw rate value ($\dot{\Psi}_{fil}$) and/or by a lateral acceleration value (ay).

9. The method as claimed in claim 1, characterized in that the predefined operating state of the vehicle is straight-ahead travel occurring at a

minimum velocity.

10. The method as claimed in claim 1, characterized in that the friction coefficient value (Fµ) is determined by evaluating the frequency distributions of values determined for an axle-related slip value (λ_{VA}, λ_{HA}), with the axle-related slip value which is determined for the driven axle being evaluated in the case of driving and the axle-related slip value which is determined for the non driven axle being evaluated in the case of braking.

11. The method as claimed in claim 1, characterized in that when brief regulating interventions of a yaw rate control device occur the friction coefficient value (Fµ) is determined by evaluating the frequency distributions values determined for the wheel slip values (λij).

12. The method as claimed in claim 1, characterized in that wheel friction coefficient values (Fλij) are determined in each case by evaluating the frequency distributions of values determined for the wheel slip values (λij), with the friction coefficient value (Fµ) being determined as a function of the wheel friction coefficient values (Fµij).

13. The method as claimed in claim 12, characterized in that the friction coefficient value (Fµ) is determined as a function of various values which include the wheel friction coefficient values (Fµij), by means of plausibility interrogations.

14. The method as claimed in claim 13, characterized in that in the plausibility interrogations not only the wheel friction coefficient values (Fµij) are taken into account

but also a variable (μPlausVA, μPlausHA) which constitutes a measure of the friction coefficient value utilized at the front axle or rear axle of the vehicle in the present driving situation, and/or a variable (FEAAZ) which contains information about the state of the closed-loop and/or open-loop control devices contained in the vehicle, and/or a variable ($T_{außen}$) describing the outside temperature and/or a variable (F_{Regen}) originating from a rain sensor and/or a variable ($F_{Scheibenwischer}$) representing the operating state of the windshield wiper and/or a signal (BLS) representing the activation of the brake pedal by the driver.

15. The method as claimed in claim 1, characterized in that an estimate of the coefficient of friction utilized in the driving situation is taken into account in the determination of the friction coefficient value (Fμ).

16. The method as claimed in claim 1, characterized in that the friction coefficient value (Fμ) includes at least two values, with a first value representing a slippery underlying surface and a second value representing an underlying surface with good grip.

17. The method as claimed in claim 16, characterized in that the distance traveled by the vehicle and/or a time condition are taken into account when switching over between the values.

18. The method as claimed in claim 17, characterized in that the switching over from the one value which represents a slippery underlying surface to the other value which represents an underlying surface with good grip is not performed

until the vehicle has covered a predefined distance.

19. The method as claimed in claim 17, characterized in that the switching over from the one value which represents an underlying surface with good grip to the other value which represents a slippery underlying surface is not performed until a predefined period of time has passed.

20. The method as claimed in claim 1, characterized in that during the predefined operating state of the vehicle the maximum value of a velocity change value (a_{xFilt}) is determined, with this value being taken into account during the evaluation of the frequency distribution of values.

21. The method as claimed in claim 1, characterized in that the wheel slip values (λij) are determined during the predefined operating state of the vehicle only for a predefined period of time which is defined by a minimum period of time and/or a maximum period of time.

22. The method as claimed in claim 1, characterized in that a variable ($T_{außen}$) which describes the outside temperature and/or a variable ($F_{Scheibenwischer}$) which represents the operation of the windshield wiper are determined, with the determination of the frequency distribution of values being eliminated or aborted when the condition which is defined as a function of at least one of these two variables is present, and a predefined friction coefficient value ($F\mu$) being used instead.

23. The method as claimed in claim 1, characterized in that the frequency distribution of values which is determined is compared with

predefined frequency distributions which are determined for different friction coefficient values, with that friction coefficient value which is associated with the predefined frequency distribution which corresponds to the determined frequency distribution of values being determined as the friction coefficient value.

24. The method as claimed in claim 23, characterized in that a velocity change value (a_{xFilt}) is used as a further feature for differentiating the predefined frequency distributions.

25. The method as claimed in claim 24, characterized in that in each case a value range for the velocity change value (a_{xFilt}) is assigned to the predefined frequency distributions, with the maximum value of a velocity change value (a_{xFilt}) being determined during the predefined operating state of the vehicle and a comparison of the determined frequency distribution of values being made only with the predefined frequency distributions in whose value range the maximum value of the velocity change value (a_{xFilt}) for the velocity change value (a_{xFilt}) is present.

26. The method as claimed in claim 23, characterized in that the value range for the wheel slip values or the axle-related slip values is divided into a plurality of slip classes, with the frequencies which are present for the individual slip classes being compared during the comparison of the determined frequency distribution of values with the predefined frequency distributions.

27. The method as claimed in claim 12, characterized in that the wheel friction coefficient values ($F\mu ij$) are determined as a

function of a first variable (g) which describes the variation, related to the wheel slip, of the frequency distribution of values determined for the respective wheel slip value (λij), and a second variable which corresponds to the maximum frequency of occurrence of all the slip classes which are associated with the frequency distribution of values.

28. The method as claimed in claim 27, characterized in that the wheel friction coefficient values (Fμij) are determined by comparing the values of the first variable and of the second variable with value pairs which are predefined for conditions for an underlying surface with good grip and conditions for a slippery underlying surface.

29. A device for determining a friction coefficient value (Fμ) which represents the coefficient of friction present between the underlying surface and a vehicle tire,
in which a wheel slip value (λij) is determined for at least one vehicle wheel which describes the wheel slip present at this vehicle wheel, and
in which the friction coefficient value (Fμ) is determined as a function of the wheel slip value (λij), characterized in that, during a predefined operating state of the vehicle, wheel slip values (λij) are determined at various times, in particular successive times, and the frequency distribution of values is determined for these wheel slip values (λij) or for axle-related slip values (λ_{VA}, λ_{HA}) which are determined as a function of these wheel slip values (λij), with the friction coefficient value (Fμ) being determined by evaluating this frequency distribution of values.

30. The device as claimed in claim 29, characterized in that the friction coefficient value (Fμ) is fed to a display device (105, 311) with which the information of the friction coefficient value (Fμ) is displayed to the driver, and/or in that the friction coefficient value (Fμ) is fed for further processing to other closed-loop and/or open-loop control devices (106) arranged in the vehicle, and/or in that the friction coefficient value (Fμ) is fed to a warning system (310) which is contained in the vehicle and which uses a navigation system to determine the course of the road over the stretch in front of the vehicle and which uses a display device (105, 311) to point out hazardous locations in the course of the road to the driver by including road signs symbolizing hazardous locations in the display.

31. The use of the method as claimed in claim 1 in a warning system which uses a navigation system to determine the course of the road over the stretch in front of the vehicle and which uses a display device (105) to indicate hazardous locations such as bends and/or traffic circles and/or intersections in the course of the road to the driver by including road signs symbolizing hazardous locations in the display.